Utilization of Construction and Demolition Waste as Recycled Aggregate in Pavement Layers: A Sustainable Approach to Road Construction

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Abstract

In the Roads and Highway construction the granular course layer such as GSB (Granular Sub Base) and WMM (Wet mix macadam) are the most important layer. With the use of these layers in Flexible Payment Road a stable surface can be formed. The constructions of roads consume natural valuable resources like aggregate which is costlier. The use of recycled aggregate instead of virgin aggregate helps in reducing the demand of extraction. If a new Road is formed over the existing road or if bridge is constructed over the existing road due to increasing in day to day traffic demand than for the construction of newly road the valuable aggregate of existing road can be utilized as secondary aggregate in the replacement of virgin aggregate. In present study the granular course layer of flexible pavement such as GSB and WMM are investigated experimentally to form with excavated aggregate material produced from existing road to construct fresh road. In this study it also believed that magnificent preservation of natural and valuable resources would be attained from the inclusion of secondary and tertiary materials in roadconstruction

Key Words: GSB (Granular Sub Base), WMM (Wet mix macadam), Recycled Aggregate, Road Demolition Wastes, Road Dismantling Materials, Road Granular Waste.

INTRODUCTION

Recycling of aggregate as Road Demolition Wastes is a process in which existing road aggregate is reused for new road construction. Use of secondary (recycled) aggregate in road construction is not very usual in India and other developing nations. The aggregate is valuable material and there is huge requirement of the aggregate as the traffic is increasing day to day with fast development in the infrastructure area. It is required to reduce the usage of virgin aggregate. In continuation of this step the RD aggregate could be used in the replacement of new material. If there is a provision of new construction of road over the existing road or if there is requirement of bridge at the existing junction then in such case the requirement of aggregate can be full filled with the dismantling of existing roadway cutting in the form ofaggregate.

In this paper the secondary aggregate is contracted from the granular of dismantled roads. For a developing nation the highways and road infrastructure is an constitutive requirement for economic growth. The road network system is a way to joint other transport modes like rail-ways, air-ways etc. The growth of a country depends on a well synchronized road system. For construction of road there are multiple types of material which includes different grade of aggregate and binding material. Among this Aggregate is an important part of pavement structure. This should be of appropriate physical property as define in IRC codes. In the road construction and it's design the important role of the pavement layer is to forward wheel load of vehicles to the subgrade. In this load transfer process, the aggregates have to take stresses coming reason to the vehicles wheel load of the traffic. Therefore it is required to use aggregate that has significance properties to the highway engineers. The aggregates are further divide based on their physical characteristics such as-gradation, size, shape and texture. For designing of different pavement mixes like B.C., D.B.M., semi dense bituminous macadam and bituminous concrete it is important separate gradation as has been denoted by various parties like A. S. T. M, B. S. I, I.S.I & I.R.C. Pavement layer like Granular Layer and Bituminous Layer can be constructed by using road demolition material as recycled material

1.1 IMPORTANCE OF THESTUDY

The study "An Experimental Study on Use of Road Demolition Wastes as Recycled Materials in Pavement Construction" has been selected to determine the applicability of granular course of existing RD materials in new road construction. This will help realize the economics of road construction and save environmental degradation by reducing mining and pollution. Road construction costs are high. Material costs alone account for over 60% of total construction costs, of which total costs account for approximately 30%. We can use RD aggregates instead of new aggregates in highway construction and provide economic benefits to the project. In order to make full use of R.D. aggregates, the suitability of R.D. waste in different types of pavement components need to be discussed. For this step, the use of RD aggregate in granular base stock (G.S.B.) and Moist mixed crushed stone (W.M.M.) are described in details in upcoming chapter. The construction as well as maintenance of roads and highways involves the sum of millions of tons. Considering the lack of new aggregate, this study considered replacing some new aggregate with recycled / dismantling granular aggregate.

1.2 OBJECTIVE OF THESTUDY

The final cause of the study was to evaluate the suitability of RD materials in new road construction. The main side of the discussion includes-

(1) To collect the material for study.

(2) Investigate various characteristics of selected materials, such as grade, water absorption, M.D.D., A.I.V., F.I. & E.I. property to determine their suitability in G.S.B. and W.M.M.structures.

(3) Design of J.M.F. forG.S.B.

1.3 COMPARISION OF RECYCLED (SECONDARY) AGGREATE AND FRESH (NATURAL)AGGREATE

Location

Fresh aggregate comes from various rock sources. Processing plants for fresh aggregate depend on resources. It usually happens at mining sites and outside cities. Road Demolition Wastes as Recycled Materials comes from the fragmentation of existing roads.

Texture

Recycled aggregate has slender particles and adheres to the asphalt, while fresh aggregate is angular, round dense and smooth aggregate. When producing viable aggregates, elongated and angular particles with asphalt content require less water than smooth and round dense aggregates. The void content will increase with corner aggregates, where larger-sized wells and improved graded aggregates will reduce voidcontent.

Quality

The quality of RD aggregate and new aggregate is different. According to Sagoe and Brown (1998), the quality of new aggregate depends on the physical as well as chemical characteristics of the source site, and the source of RD materials depends on the contamination of the debris source. The report also pointed out that natural resources are suitable for a variety of products, with higher products having larger sales areas, but the product mix of recycled aggregates is limited, and lower product mixes may limit themarket.

ADVATAGE

The use of RD aggregate has lots of advantage. The advantages resulting from the Use of Road Demolition Wastes as Recycled Materials in Pavement Construction are listed below.

(1) SaveEnergy

The recycling procedure shall be performed on site. According to the Kashima Institute of Technology (2002), Kashima has developed a recycling method used in buildings called the on-site recycling system. Through this system, everything from recycled aggregates to manufacturing and use can be done at the building site. This saves energy and transports recycled materials to recyclingplants

(2) Environmental Gain

The main avail is based on environmental benefits. C.S.I.R.O., there is most of land area there is about 40% of the total landfill waste is available that could be used for building and demolition each year. By recycling this material, the resources that cities gather can be continuously reduced. Therefore, new aggregate may used for higher grade applications.

(3) Cost

The cost of RD aggregate is lesser than new aggregate. The cost of aggregate depends on the local availability. This is only about half the cost of new aggregates used in construction of projects. The transportation cost of RD aggregate is diminished due to local availability. RD aggregates from demolition projects can save the cost of moving materials to landfills and save disposal costs. In addition, the Aggregate Consulting Services also pointed out those recycling sites can accept lower costs without taxation than landfills, and that in construction projects, the price of RD aggregates can be lower than the price of main aggregates. With the help of RD aggregate, the cost of overall project can be reduced without compromising with permissible limit specified by MORT&H.

(4) Market iswide

The market for Road dismantling aggregates is broad. According to the regulations organized by the Environmental Committee, road dismantling aggregates shall be utilized for bridge, substructures and concrete structure,filter media. It is also stated that road dismantling aggregates may be used in recourse layers such as bottom layers and non-sterile bottom layers and permeable bottom layers.

(5) Sustainability

By using recycled aggregates, the quantity of road waste used in landfills will be reduced. This will extenuate the number of quarrying. This will therefore increase the life of all available resources that is natural, and also the life of landfillsites.

(6) Future Scope of Work

Currently, due to the huge prosperity of the construction industry and the environment, mining has a big problem, and this problem may increase exponentially in the future. Therefore, it is a noble idea to recycle the aggregate obtained from RD waste. In this study, the test results pointed that the mixture of G.S.B and W.M.M. using RD aggregates complies with MORTHspecifications.

This study may expand in the following directions –

(a) The comparison of RD material shall also be utilized to study with the properties of other mixtures, such as asphalt andgravel.

(b) The effect on economic part may also part of future analysis that might help to determine the financial benefits by using RD material in the replacement of newmaterial.

(c) The field performance of the test section with RD material may also be part of futureresearch.

(d) The effects of Road dismantling aggregate treated by methods such as the H.R.M. may also be included in nextstudies.

EXPERIMENTAL PROGRAMME

INTRODUCTION

Detailed study of the experimental work on Road Demolition Wastes as Recycled Materials has been discussed in this chapter. Job mix formula (gradation), proctor test, C.B.R. test, permeability test for G.S.B. and W.M.M. have been studied by adding Road demolition wastes as recycled aggregate with stone dust in various proportion.

RESEARCH OBJECTIVES

When there is a provision of any structure like VUP/PUP/CUP or MNB/MJBover existing road then the main layer of existing road layer is required to dismantlefor this new proposed project. In such case the valuable layer of existing road likeBituminous Course and Granular Course extracted from dismantling process. Thesevaluable layers can be reuse for construction of approaches of proposedVUP/PUP/CUP or MNB/MJB or can be reuse for its proposed service road.

While using recycled aggregate like road demolition wastes for the making of new road layer, it is important to design its proportion so it may sustain under the heavy loads of vehicle. It is also important to find the percentage of recycled aggregate that can be reuse which will define the MORT&H specification limits. The main cause of this researchinclude-

(1) To collect the material forstudy.

(2) Investigate various characteristics of selected materials, such as grade, water absorption, M.D.D., A.I.V., F.I. & E.I. property to determine their suitability in G.S.B. and W.M.M.structures.

(3) Design of JMF for G.S.B. by adding Road demolition wastes as recycled aggregate in variousproportions.

(4) Design of JMF for W.M.M. by adding Road demolition wastes as recycled aggregate in variousproportions

EXPERIMENTAL PROGRAMME DETAILS

An experimental programme was setup to investigate the changes develop before and after using of recycled aggregate of road demolition wastes with fresh aggregate. The main aim was to find out average percentage of fresh aggregate of course aggregate can be replaced with recycled aggregate also investigate the changes develop in characteristics of fresh aggregate after addition of recycled aggregate of road demolition wastes in grade, water absorption, Max. Dry Density, A.I.V., flake property and elongation to determine their applicability in G.S.B. and W.M.M. structures.

MATERIALS USED

The materials used for developing the road layers of fresh G.S.B. and W.M.M. after addition of recycled aggregate of road demolition have been described this way.

RoadAggregate

In Road construction, **Aggregate** is a grainy material, such as sand, gravel, and crushed stone which is an expanded category of coarser-to-medium-grained materials that is used in construction of sub base course and base course layer. Mainly road aggregate are further categorized in Fine Aggregate and Course Aggregate. Here in this experimental programme we use course aggregate as fresh aggregate that will use with recycledaggregate.

Coarse Aggregate

Coarse particles will not be passing through a sieve metering 4.75mm opening. The coarse aggregates may be produced fictitiously or can be available naturally. The limit size of the coarser aggregate used in running study is 40mm which confirming to IS Code -383-1970. The figure of 40mm sample courser aggregate has been shown in fig 3.1. Sieve designation use for aggregate grading requirements of single sized 40 mm aggregate is 40mm, 20mm and 10mm which has been shown in Table no. 3.1.

Sr. No.	Sieve Metering (mm)	Cumulative % by Wt. of Total Aggregate Pass
1	63mm	100
2	40mm	85 - 100
3	20mm	0 - 20
4	10mm	0 - 5

Recycled Aggregate

Recycled aggregate is formed by dismantling / excavation of granular layer of existing road. If any structure such as VUP / PUP / CUP or MNB / MJB is provided on the existing road, the main layer of the existing road needs to be demolished for this newly proposed project. In this case, valuable layers of existing roads, such as asphalt layers and particle layers, were extracted from the demolition process. These valuable layers can be reused to construct the proposed VUP / PUP / CUP or MNB / MJB methods, or they can be reused for their proposed servicepath.

In such case when there is required to demolish the granular layer of existing bituminous road, than the main layer of existing road ie G.S.B. and

W.M.M. are excavated. But in this step both the layer of G.S.B. and W.M.M. are difficult to dismantle individually. In most of case both the layer are excavated combinedly and stored as a recycled material that will use for construction of new granular layer of pavement. It is eminent that road construction costs are high. Material cost alone register for more than 60% of the total building cost, of which the total cost accounts for about 30%. We can use RD aggregates to replace new aggregates in

highway road pavement construction and bring economic benefits to the project. In order to make full use of RD aggregates, it is required to discuss the suitability of RD waste in discontiguous types of road components such as flexible pavement. In this study, the use of RD aggregate in granular base material (G.S.B.) and wet mixed crushed stone (W.M.M.) was evaluated.

In the present investigation, the recycled aggregates of G.S.B. and W.M.M. are use for construction of new road. The study includes the use of RD granular aggregate with addition of fresh 40 mm courser aggregate and stone dust in various proportions.

Recycled aggregate use in this study are further described as below :

Granular Course

In existing road pavement structure the granular course is available in base / sub base layer. It is further find in two proportions of G.S.B. and W.M.M..

Granular Sub Base (G.S.B.)

G.S.B. is a type of drainage layer and it is also type of good subbase to laid base layer on it. The materials used for this work should be natural sand, crushed stone, crushed stone, crushed slag, or a combination of them, depending on the grade required by the grade.

Materials such as brick metal, Kanka, and crushed concrete should be used in the following metal base. The material should be free of organic or other harmful ingredients.

Classes III and IV must be used in the lower subbase. Classes V and VI will be used as sub layers and drainage layers. A figure of G.S.B. bed is shown in fig.3.2.

For this study it is important to know the grading and physical properties of G.S.B., so while using RD aggregate the specified grading and physical properties of

GSB can be maintained. According to the Ministry of Road Transport and Highways (MORT&H) the aggregate use for laying is required to fulfill the grading limits which are shown in Table no.

Sieve Designation (mm)	% by Weight Passing the Sieve					
	Type 1	Type 2	Type 3	Type 4	Type 5	Type 6
75.0	100	-	-	-	100	-
53.0	80 to 100	100	100	100	80 to 100	100
26.5	55 to 90	70 to 100	55 to 75	50 to 80	55 to 90	75 to 100
9.50	35 to 65	50 to 80	-	-	35 to 65	55 to 75
4.75	25 to 55	40 to 65	10 to 30	15 to 35	25 to 50	30 to 55
2.36	20 to 40	30 to 50	-	-	10 to 20	10 to 25
0.85	-	-	-	-	2 to 10	-
0.425	10 to 15	10 to 15	-	-	0 to 5	0 to 8
0.075	Less than 5	Less than 5	Less than 5	Less than 5	-	0 to 3

The study of physical requirements of G.S.B. is also required for considering the specification of MORT&H. The physical requirements for materials for G.S.B. is shown in Table no.3.3

A.I.V.	IS Code: 2386 (Part 4} or IS Code: 5640	40 maximum
L.L.	IS Code: 2720 (Part 5)	Maximum 25
P.L.	IS Code: 2720 (Part 5)	Maximum 6
C.B.R. at 98% Dry Density (at IS Code: 2720 - Part 8)	IS Code: 2720 (Part 5)	Minimum 30

The physical requirement is need to fulfill while using the recycled aggregate with appropriate percentage of fresh aggregate so the layer of base / sub base can be laid with structural strength.

Here is required physical properties of

G.S.B. is shown that will maintain during study.

- Max. thickness of 1 hard dense layer =200mm
- Mini. thickness of 1 hard dense layer =150mm
- Max. allowable size of particle=75mm
- Number of G.S.B. grading =6
- L.I. should not be greater than 25% (IS Code: 2720 (part5).
- P.I. should not be greater than 6% (IS Code: 2720 (part5).
- A.I.V. should not be higher than40%.
- C.B.R. value required to be lesser than 30%.
- FDD required not be less than 98% ofM.D.D..
- 1 test/ 1000 square meter should be done during checking ofFDD.
- M.C. = 1 – 2 % belowO.M.C.

Wet Mix Macadam (W.M.M.)

W.M.M. serves as the base layer which is laid on subbase layer and just below to BC. It forward the receiving load from BC to subbase layer. A figure of W.M.M. layer of flexible pavement is shown in fig

For this study, it is important to analysis the grade and physical properties of W.M.M., so when using RD aggregates, the specified grade and physical properties of

W.M.M. can be maintained. According to the requirements of the Ministry of Road Transport and Highways (MORT & H), the total use of the paving must meet the grade limits shown in Table

Sieve Designation	% by Wt. passing Sieve
53.00 mm	100
45.00 mm	95 – 100
26.50 mm	-
22.40 mm	60 – 80
11.20 mm	40 – 60
4.75 mm	25 – 40

2.36 mm	15 – 30
600.00 micron	8 – 22
75.00 micron	0 – 5

The final grades approved within these ranges should be from coarser to finer grades, and not from the lower limit of one screen to the upper limit of adjacent screens, and vice versa. In order to consider the specifications of MORT & H, it is also necessary to study the physical requirements of the W.M.M. The material physical requirements of the W.M.M. are shown in Table

In order to determine the combined part, the flaky stone should be first separated from the representative sample. The flake index is the weight of the flake stone divided by the wt. of the stone sample. Only the elongated aggregate particles are separated from the rest (non-flaky) stone aggregate. The values of the obtained brittleness index and E.I. are added. The E.I. is the elongated particles's weight divided by the sum of non-flaky particles.

The P.I. of materials smaller than 425 microns does not exceed to 6. If the water soaking value of the coarser aggregate is greater than 2%, the stability of the material shipped to the site should be tested in accordance with IS Code: 2386 (Part 5).

Before using stone dust with recycled aggregate of road demolition wastes, it required to fulfill the specific limits of IS Code: 383 : 2016

that has been shown in Table

Sr. No.	Sieve Designation	% by Wt. Passing Sieve			
		Grading I	Grading II	Grading Ill	Grading IV
1	10 mm	100	100	100	100
2	4.75 mm	90 - 100	90 - 100	90 - 100	95 - 100
3	2.36 mm	60 - 95	75 - 100	85 - 100	95 - 100
4	1.18 mm	30 - 70	55 - 90	75 - 100	90 - 100
5	0.600 mm	15 - 34	35 - 59	60 - 79	80 - 100
6	0.300 mm	5 - 20	8 - 30	12 - 40	15 - 50
7	0.150 mm	0 - 10	0 - 10	0 – 10	0 - 15

S. No.	Test	Test Method	Requirements
1	Los Angeles Abrasion value or A.I.V.	IS Code: 2386 Part-4 IS : 2386 Part-4 or IS : 5640	40%(Max.) 30%(Max.)
2	Combined F.I. & E.I. (Total)	IS Code: 2386 Part-1	35% (Max.)*

ACQUIREMENT OF ROAD DEMOLITION MATERIAL

In this experimental programme the changes develop before and after using of recycled aggregate of road demolition wastes with fresh aggregate was setup to investigate. For this study road demolition wastes as recycled aggregate was collected in form of granular course. In flexible pavement an important layer of granular course is laid for proving structural strength to the pavement and it also helps to maintain the shape of pavement section under different moveable loads of vehicles. The granular layer is further found into two groups – 1. G.S.B. and 2. W.M.M..

The course aggregate found in existing road demolition process was in mix proportion of G.S.B. and W.M.M. material. In structural design of flexible pavement both the layers were laid on each other. It was difficult to excavate the existing road layer of G.S.B. and WMM separately. Fig 3.4 shows the excavated granular aggregate of G.S.B. and W.M.M.

These valuable layers shall be utilized in construction of fresh roads. But the mix of aggregate is available with different size particles. For the building of new granular layer of pavement with road demolition wastes first it is essential to cross the collected sample through tests. It should meet the grading criteria specified by MORT&H.

GRADATION OF ROAD DEMOLITATION WASTE

Gradation of road demolition waste was performed with reference IS Code383-2016 and MORT&H. Fresh Courser aggregate is used to mix with road demolition waste by 0%, 5%, 10%, 15% and 20% by Wt. of road demolition waste. In this study programme almost 80% of road demolition waste is utilized in construction of new granular layer of pavement. For increasing the strength property of pavement

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For checking the particle size whether under the as stipulated limits of MORT&H or not, the sieve analysis process taken place. The sieve analysis for road demolition waste as granular course is performed in lab. Before staring the test, first it is required to oven dry the sample at 105 ˚C to 110 ˚C than weighted the sample.

While testing, each and every sieve shall be separately shaken on a discernible rosette for not lesser than 2 mints. When dangle, it should be carried out in different actions, astern and onward, left face

and right face, dextral and counterclockwise staggering, And often vibrate to keep the material in the direction of the sieve surface changes frequently. Materials must not try to pass through the sieve by hand. On completion of each sieving the wt. shall be noted and sieve size wise make a record in a table. The data in table includes retained wt. (gm), cumulative retained wt. (gm), % cumulative retained wt. and % passing. In fig. 3.5 different size sieves and the test for sieve analysis are shown

Study on Use of Road Demolition Waste for Fresh G.S.B.Laying

As we have discussed previously in this study (Ref. 3.4) that road demolition wastes of granular course is found in mix size particles of two major layers. For utilizing of dismantled granular waste as fresh G.S.B. layer, first it is required to fulfill the specification requirement of gradation test in which its limits are specified by MORT&H (Ref. Table

For utilizing the dismantling material of granular course in construction of fresh pavement layer, three samples were collected for gradation and check whether its particle were laying in between specified limit of MORT&H (Ref. Table 3.2). Table no. 3.7 shows the sieve analysis of road demolition waste of sample no. 1. In this analysis the sieve of size 75mm, 53mm, 26.50mm, 9.50mm, 4.75mm, 2.36mm, 425micron and 75micron followed by MORT&H were used

Sieve Analysis of Road Demolition Waste for New G.S.B. Laying

Sample No.				1		
A. Wt. of Sample (gm)				30115		
Sieve Metering 'mm'	Retained Wt. (gm)	Cumulative Retained Wt. (gm)	Cumulative Retained Wt. %	% Passing	Limits as Per MORT&H	
					Lower	Upper
75.00	0	0	0.00%	100.00 %	100	100
53.00	0	0	0.00%	100.00 %	80	100
26.50	7512	7512	24.94%	75.06 %	55	90
9.50	7132	14644	48.63%	51.37 %	35	65
4.75	2699	17343	57.59%	42.41 %	25	55
2.36	3331	20674	68.65%	31.35 %	20	40
0.425	4614	25288	83.97%	16.03 %	10	15
0.075	2999	28287	93.93%	6.07%	0	5

In this analysis the waste material of dismantled granular course seems to be little finer as it is mix material of excavated G.S.B. and W.M.M. In sample no. 1 the lower Sieve Metering 425microm and 75microm crosses the specified limit which is not suitable for preparing of fresh G.S.B. bed.

For detailed study sieve analysis of road demolition waste is taken place for sample no. 2. Table no. 3.8 shows the sieve analysis of sample no. 2.

Sample No.	2					
A. Wt. of Sample (gm)	28600					
Sieve Metering 'mm'	Retained Wt. (gm)	Cumulative Retained Wt. (gm)	Cumulative Retained Wt. %	% Passing	Limits as Per MORT&H	
					Lower	Upper
75.00	0	0	0.00%	100.00%	100	100
53.00	0	0	0.00%	100.00%	80	100
26.50	7311	7311	25.56%	74.44%	55	90
9.50	6773	14084	49.24%	50.76%	35	65
4.75	2645	16729	58.49%	41.51%	25	55
2.36	3163	19892	69.55%	30.45%	20	40
0.425	4381	24273	84.87%	15.13%	10	15
0.075	2787	27060	94.62%	5.38%	0	5

Combined Flakiness and Elongation-

Shape tests of amended / modified W.M.M. aggregates such as F.I. and E.I. are important. Aggregate used in the construction of W.M.M. shall be in range of F.I. and E.I. specified by IS code - 2386 (Part -1) : 1963 and MORT&H (Ref. Table no. 3.5). For conducting test we used a standard length gauge, a standard thickness gauge, IS sieves metering 63, 50 40, 31.5, 25, 20, 16, 12.5,10 and 6.3mm conforming to IS Code: 460 Part I – 1985 & a balance of capacity 5kg (accurate up to 1gm).

Sieve Metering (mm)		F.I.			E.I.		
Passing through IS Sieves (mm)	Retained on IS Sieves (mm)	Flakiness Gauged (mm)	Wt. of the Friction Gauge (g)	Wt. Passing on Flakiness Gauge (g)	Elongation Gauged (mm)	Wt. of the Friction Gauge (g)	Wt. Retained on Elongation Gauge (g)
63	50	33.9	For Sieve wise Wt. of the Friction Gauge result Ref. Table No. 4.15	For Sieve wise Wt. Passing on Flakiness Gauge result Ref. Table No. 4.15	--	For Sieve wise Wt. of the Friction Gauge result Ref. Table No. 4.15	For Sieve wise Wt. Retained on Elongation Gauge result Ref. Table No. 4.15
50	40	27			81		
40	31.5	19.5			58.5		
31.5	25	16.95			--		
25	20	13.5			40.5		
20	16	10.8			32.4		
16	12.5	8.55			25.6		
12.5	10	6.75			20.2		
10	6.3	4.89			14.7		
Total							

Calculation –

The F.I. % = Wt. of Agg. Passing through Flakiness Gauge x 100 / Total Wt. of the Friction Gauged

The E.I. % = Wt. of Agg. Retained through Elongation Gauge x 100 / Wt. of the Friction Gauge

The combined F.I. and E.I. for amended / modified W.M.M. aggregates should not be more than 35%

Aggregate Impact Value–

This test was done to determine the A.I.V. of amended / modified W.M.M. material (Ref. Para no.- 3.5.2.1) as per IS Code : 2386 (Part IV) – 1963. For finding the A.I.V. of amended / modified W.M.M. material we took three sample and the process was followed similarly to the A.I.V. test of G.S.B.

Calculation –

For finding M.D.D. & O.M.C. of amended / modified W.M.M. material a graph was plotted between Dry Density (gm/cc) and % M.C.. Then we draw a smooth curve through the result points and determine the position of the maximum value on the curve, which is called the M.D.D. The corresponding M.C.is called the O.M.C

SUMMARY

In the above experimental program, road demolition wastes of granular courses were taken for utilizing in construction of new road layer. Such granular wastes were tested for checking gradation property and some Improvement was made in gradation according to their grading requirement. In continuation of this Physical tests were also performed for amended / modified material such as water absorption test,Atterberglimitstest,combinedF.I.andE.I.,A.I.V., M.D.D.&O.M.C.and

C.B.R. test.

RESULT AND DISCUSSION

GRADATION TEST FOR IMPROVED GSBMATERIAL

In continuation of Para no. 3.5.1.1 of previous chapter 20% of 40mm fresh aggregate was used with acquired road demolition wastes (Ref. Para no. 3.4) and by following the process, the gradating requirements were comes under specified limit of Table

The results derived in sieve analysis process are mentioned in Table

Sieve Analysis of modified G.S.B. Material

Sieve Metering 'mm'	% Passing	Mid-Range	As Per MORT&H Limits	
			Lower	Upper
75.00	100.00%	100.00	100	100
53.00	100.00%	90.00	80	100
26.50	72.51%	72.50	55	90
9.50	48.43%	50.00	35	65
4.75	39.69%	40.00	25	55
2.36	28.80%	30.00	20	40
0.425	12.31%	12.50	10	15
0.075	2.60%	2.50	0	5

The results of sieve analysis are nearly to the mid-range. In the experimental study we can say that the road demolition wastes of granular course can be reuse for construction of new G.S.B. layer after addition of 20% 40mm course aggregate.

PHYSICAL TESTS FOR IMPROVED G.S.B. MATERIAL

It is not sufficient to fulfill the gradation requirements only for construction of new G.S.B. road layer. Other physical tests are also play an important part to check the wearing strength of layer under heavy loads for which it is design. These tests include water absorption, atterberg limit, A.I.V., M.D.D. & O.M.C. and C.B.R. The tests were conducted for samples of previous chapter to find conclusiveresult.

Water Absorption Test-

Water absorption test was performed to find the porous property of amended / modified G.S.B. material (Ref. Para no.- 3.5.1.1). This will affect the wearing capacity of layer and could become reason for layer failure. The procedure was followed by IS code 2386 (Part 3) : 1963 and the results of these sample has been shown in table

Water Absorption Test Result of amended / modified G.S.B.material

Sr. No.	Description	Sample 1	Sample 2	Sample 3	Average %
A	Wt. of SSD Material in gm	2037	2084	2055	0.68
B	Wt. of Oven Dry material in gm	2022	2069	2043	
C	Absorption (A-B)/B x 100 (%)	0.74	0.72	0.59	

The results of average of three samples were found 0.68% which is under limit ofMax.2%specifiedbyIScode2386(Part3):1963.So,theamended/modified G.S.B. material passes the test.

Atterberg Limits (L.L., P.L., & P.I.)-

For determining the L.L of amended / modified G.S.B. material the Cone Penetrometer Method was adopted accordance with IS code 2720 (Part 5) – 1985. The two samples were taken for testing and steps were followed as described in para no.

3.6.2. The results derived from test of sample no. 1 has been shown in Table

Atterberg Limits by Cone Penetrometer of G.S.B. Material for Sample 1

S. No.	Determination Detail	L.L.				P.L.		
		1	2	3	4	1	2	Avg.
1	Penetration Depth	15	18	22	27			
2	Vessel Identification No.	B13	B6	B8	B3	N.P.		
3	Wt. of Blank Vessel, gm (A)	20	20.30	20.30	18.10			
4	Wt. of Moist Soil + Vessel, gm (B)	50.31	53.28	47.44	49.99			
5	Wt. of Dry Soil + Vessel, gm (C)	45.73	47.81	42.68	43.85			
6	Wt. of Water, gm D = (C-B)	4.58	5.47	4.76	6.14			
7	Wt. of Dry Soil, gm E = (C-A)	25.73	27.51	22.38	25.75			
8	% M.C. = (D/E)x100	17.80	19.88	21.27	23.84			

Atterberg Limits by Cone Penetrometer of G.S.B. Material for Sample 2

S. No.	Determination Detail	L.L				P.L.		
		1	2	3	4	1	2	Avg.

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1	Penetration Depth	16	19	21	26		
2	Vessel Identification No.	B21	B22	B23	B24		
3	Wt. of Blank Vessel, gm (A)	23.8	23.9	23.9	23.9	N.P.	
4	Wt. of Moist Soil + Vessel, gm (B)	50.08	54.71	54.88	58.23		
5	Wt. of Dry Soil + Vessel, gm (C)	46.21	49.61	49.42	51.6		
6	Wt. of Water, gm D = (C-B)	3.87	5.1	5.46	6.63		
7	Wt. of Dry Soil, gm E = (C-A)	22.41	25.71	25.52	27.7		
8	% M.C. = (D/E) x 100	17.27	19.84	21.39	23.94		

Test Result of M.D.D. & O.M.C. of G.S.B. Material for Sample – 1

Trail No.	1					
Wt. of Mold W (gm)	7968					
Volume of Mold V (in cc)	2250					
1] Assessment No		1	2	3	4	5
2] Wt. of Mold + Moist Soil	Gm	12445	12822	13198	13126	12898
3] Wt. of Moist soil	Gm	4477	4854	5230	5158	4930
4] Bulk Density	gm/cc	1.99	2.16	2.32	2.29	2.19
5] Vessel No.		1	2	3	4	5
6] Wt. of Vessel	Gm	75.70	77.60	77.50	73.60	76.90
7] Wt. of Vessel + Moist soil	Gm	244.51	275.39	284.59	298.25	279.33
8] Wt. of Vessel + Dry Soil	Gm	240.99	267.49	271.62	280.99	260.53
9] Wt. ofWater	Gm	3.52	7.90	12.97	17.26	18.80
10] Wt. Of Dry Soil	Gm	165.29	189.89	194.12	207.39	183.63
11] M.C.	%	2.13	4.16	6.68	8.32	10.24
12] Dry Density	gm/cc	1.948	2.071	2.179	2.116	1.988

Test Result of M.D.D. & O.M.C. of G.S.B. Material for Sample – 2

Trail No.	2					
Wt. of Mold W (gm)	7968					
Volume of Mold V (in cc)	2250					
1] Assessment No		1	2	3	4	5
2] Wt. of Mold + Moist Soil	gm	12363	12802	13206	13188	12853
3] Wt. of Moist soil	gm	4395	4834	5238	5220	4885
4] Bulk Density	gm/cc	1.95	2.15	2.33	2.32	2.17
5] Vessel No.		6	7	8	9	10
6] Wt. of	gm	75.20	76.40	73.00	74.40	74.10

Vessel						
7] Wt. of Vessel + Moist soil	gm	286.02	263.49	253.58	225.56	231.48
8] Wt. of Vessel + Dry Soil	gm	281.74	256.16	242.69	214.29	217.00
9] Wt. ofWater	gm	4.28	7.33	10.89	11.27	14.48
10] Wt. Of Dry Soil	gm	206.54	179.76	169.69	139.89	142.90
11] M.C.	%	2.07	4.08	6.42	8.06	10.13
12] Dry Density	gm/cc	1.914	2.064	2.188	2.147	1.971

Moisture Content and Unit Wt. of Test Sample

S. No	Description	Mold No. 1		Mold No. 2		Mold No. 3	
A.	No. of layers	5		5		5	
B.	No. of blows per layer	56		56		56	
C.	Socking Condition	Before	After	Before	After	Before	After
D.	Wt. of Mold (gm)	6942	6942	7338	7338	7401	7401
E.	Wt. of Moist soil + mold (gm)	12183	12234	12581	12591	12644	12656
F.	Wt. of Moist soil (E-D) (gm)	5241	5292	5243	5253	5243	5255
G.	Volume of Mold (cc)	2250	2250	2250	2250	2250	2250
H.	ρ (Wet) = (F/G) (gm/cc)	2.329	2.352	2.330	2.335	2.330	2.336
J.	Moisture Assessment						
K.	Vessel no.	1	1	2	2	3	3
L.	Wt. of Vessel (gm)	75.7	75.7	77.6	77.6	77.5	77.5
M.	Wt. of moist soil + Vessel (gm)	345.2	325.5	290.45	265.52	270.52	295.45
N.	Wt. of dry soil + Vessel (gm)	328.04	307.23	276.90	253.14	258.23	281.02
P.	Wt. of water (M-N) (gm)	17.16	18.27	13.55	12.38	12.29	14.43
Q.	Wt. of dry soil (N-L) (gm)	252.34	231.53	199.30	175.54	180.73	203.52
R.	W.C. [(P/Q)x100] (%)	6.80	7.89	6.80	7.05	6.80	7.09
S.	Dry Density - {H/[1+(R/100)]} (gm/cc)	2.181	2.180	2.182	2.181	2.182	2.181

Load Penetration Test Data

Penetration (mm)	Mold No. 1		Mold No. 2		Mold No. 3	
	Proving Ring Reading	Corrected Load (kg)	Proving Ring Reading	Corrected Load (kg)	Proving Ring Reading	Corrected Load (kg)
0	0	0	0	0	0	0
0.5	26	112.84	26	112.84	24	104.16
1	48	208.32	49	212.66	48	208.32
1.5	81	351.54	85	368.9	84	364.56
2	111	481.74	125	542.5	111	481.74
2.5	139	603.26	144	624.96	141	611.94
3	161	698.74	162	703.98	158	685.72
4	186	807.2	190	824.6	191	828.94

		4				
5	199	863.66	211	915.74	205	889.7
7.5	232	1006.88	235	1019.9	232	1006.88
10	262	1137.08	250	1085	254	1102.36

B.R. Value of amended / modified GSB material

Description	Mold No. 1	Mold No. 2	Mold No. 3
C.B.R. at 2.5 mm Penetration	44.03	45.62	44.67
C.B.R. at 5.0 mm Penetration	42.03	44.56	43.29
Corrected C.B.R at 2.5 mm Penetration	44.35	45.41	43.51
Corrected C.B.R at 5.0 mm Penetration	42.24	45.93	44.98
C.B.R. Reported (%) 2.5 mm	44.42%		

For construction of new G.S.B. layer the C.B.R. value of material should be Min. 30% as per IS Code : 2720 (Part-16) (Ref. Table No. – 3.3). The C.B.R value obtained from tests of amended / modified GSB material was 44.42% which fulfill the minimum requirement of guideline; hence the modified material can be used for construction of new G.S.B layer

GRADATION TEST FOR IMPROVED W.M.M.MATERIAL

In continuation of Para no. 3.5.2.1 of previous chapter 10% of 40mm fresh aggregate and 1% Stone Dust were used with acquired road demolition wastes (Ref. Para no. 3.4) and by following the process, the gradating requirements were comes under specified limit of Table no. 3.4. The results derived in sieve analysis process are shown in Table no.

The results of sieve analysis are nearly to the mid-range. In the experimental study we can say that the road demolition wastes of granular course can be reuse for construction of new W.M.M. layer after addition of 10% 40mm course aggregate and 1% Stone Dust.

Sieve Analysis of modified W.M.M. Material

Sieve Metering 'mm'	% Passing	Mid-Range	As Per MORT&H Limits	
			Lower	Upper
53.00	100.00%	100	100	100
45.00	97.37%	97.50	95	100
22.40	70.65%	70.00	60	80
11.20	50.51%	50.00	40	60
4.75	32.99%	32.50	25	40
2.36	22.80%	22.50	15	30
0.600	15.22%	15.00	8	22
0.075	2.57%	2.50	0	5

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Water Absorption Test Result of amended / modified W.M.M. material

Description	Sample 1	Sample 2	Average Value	Limit
Water Absorption Courser Agg. 40mm (%)	0.21	0.34	0.28	2% Max.
Water Absorption Courser Agg. 20mm (%)	0.94	1.02	0.98	
Water Absorption Courser Agg. 10mm (%)	0.56	0.91	0.74	
Water Absorption Stone Dust (%)	0.37	0.55	0.46	

Atterberg Limits by Cone Penetrometer of W.M.M. for Sample 1

S. No.	Assessment Detail	L.L				P.L.		
		1	2	3	4	1	2	Avg.
1	Depth of Penetration	16	19	22	26			
2	Vessel Identification No.	B21	B22	B23	B24			
3	Wt. of Blank Vessel, gm (A)	23.8	23.9	23.9	23.9			
4	Wt. of Moist Soil + Vessel, gm (B)	52.68	54.29	55.01	57.55			
5	Wt. of Dry Soil + Vessel, gm (C)	48.35	49.49	49.62	51.37			
6	Wt. of Water, gm D = (C-B)	4.33	4.8	5.39	6.18			
7	Wt. of Dry Soil, gm E = (C-A)	24.55	25.59	25.72	27.47			
8	% M.C. = (D/E)x100	17.64	18.76	20.96	22.50			

S. No.	Description	Units	Trail 1	Trail 2	Trail 3	Average
1	Wt. of Oven Dry Sample (12.5mm Passing and 10mm Retained) (X) gm	gm	363.5	359.8	360.7	361.33
2	After Impact Test - Wt. of 2.36mm Sieve Fraction Retained (Y) gm	gm	280.4	272.6	277.3	276.77
3	After Impact Test - Wt. of 2.36mm Sieve Fraction Passing (Z) gm	gm	83.1	87.2	83.4	84.57
4	A.I.V. = (Z/X)x 100	%	22.86	24.24	23.12	23.41

Atterberg Limits by Cone Penetrometer of W.M.M. Material for Sample – 2

S. No.	Assessment Detail	L.L				P.L.		
		1	2	3	4	1	2	Avg.
1	Depth of	15	19	23	27			

	Penetration						
2	Vessel Identification No.	B25	B26	B27	B28	N.P.	
3	Wt. of Blank Vessel, gm (A)	24.5	24.1	23.9	23.4		
4	Wt. of Moist Soil + Vessel, gm (B)	51.02	53.2	49.93	52.75		
5	Wt. of Dry Soil + Vessel, gm (C)	47.16	48.62	45.42	47.42		
6	Wt. of Water, gm D = (C-B)	3.86	4.58	4.51	5.33		
7	Wt. of Dry Soil, gm E = (C-A)	22.66	24.52	21.52	24.02		
8	% M.C. = (D/E) x 100	17.03	18.68	20.96	22.19		

Test Result of A.I.V. of W.M.M. Material

Test Result of M.D.D. & O.M.C. of W.M.M. Material for Trail – 1

Trail No.	1					
Wt. of Mold W (gm)	7968					
Volume of Mold V (in cc)	2250					
1] Assessment No		1	2	3	4	5
2] Wt. of Mold + Moist Soil	Gm	12562	12953	13240	13112	12980
3] Wt. of Moist soil	Gm	4594	4985	5272	5144	5012
4] Bulk Density	gm/cc	2.04	2.22	2.34	2.29	2.23
5] Vessel No.		1	2	3	4	5
6] Wt. of Vessel	Gm	75.70	77.60	77.50	73.60	76.90
7] Wt. of Vessel + Moist soil	Gm	245.50	274.50	285.60	301.20	278.20
8] Wt. of Vessel+ Dry Soil	Gm	242.12	266.76	273.51	284.03	259.06
9] Wt. ofWater	Gm	3.38	7.74	12.09	17.17	19.14
10] Wt. Of Dry Soil	Gm	166.42	189.16	196.01	210.43	182.16
11] M.C.	%	2.03	4.09	6.17	8.16	10.51
12] Dry Density	gm/cc	2.001	2.128	2.207	2.114	2.016

Test Result of M.D.D. & O.M.C. of W.M.M. Material for Trail – 2

Trail No.	2					
Wt. of Mold W (gm)	7968					
Volume of Mold V (in cc)	2250					
1] Assessment No		1	2	3	4	5
2] Wt. of Mold + Moist Soil	gm	12569	12961	13256	13102	12969
3] Wt. of Moist soil	gm	4601	4993	5288	5134	5001
4] Bulk Density	gm/cc	2.04	2.22	2.35	2.28	2.22
5] Vessel No.		6	7	8	9	10
6] Wt. of	gm	75.20	76.40	73.00	74.40	74.10

Vessel						
7] Wt. of Vessel + Moist soil	gm	244.50	273.70	286.30	304.40	279.70
8] Wt. of Vessel + Dry Soil	gm	241.03	265.91	273.41	286.99	260.18
9] Wt. ofWater	gm	3.47	7.79	12.89	17.41	19.52
10] Wt. Of Dry Soil	gm	165.83	189.51	200.41	212.59	186.08
11] M.C.	%	2.09	4.11	6.43	8.19	10.49
12] Dry Density	gm/cc	2.003	2.131	2.208	2.109	2.012

SUMMMARY

In this chapter results and discussion on the various properties of road demolition wastes as granular course with addition of 20% 40mm course aggregate have been carried out for utilizing in new G.S.B. preparation. The road demolition wastes also taken for laying of new W.M.M. layer after addition of 10% course aggregate and 1% stone dust

CONCLUSION

The conclusive results of physical test of amended / modified G.S.B. material obtained from testes are as below –

- The sieve analysis of RD waste material was not found in limits of MORT&H but after addition of 20% of 40mm course aggregate, the test results shows the requiredlimits.
- The water absorption percentage for amended / modified G.S.B. aggregate was obtained 0.68% which is under limit of Max. 2% specified by IS code 2386 (Part 3) :1963
- For Atterberg Limits, the value of average liquid limit comes out 20.85% which was found below 25% specified by IS code 2720 (Part -5) :1985.
- The plastic property was not shown during test. So, the Plasticity Index is denoted as Non – Plastic (NP).
- The A.I.V. of amended / modified G.S.B. material was found 26.61% which is less that 40% specified by IS code 2386 (Part -4) : 1963
- The Max. Dry Density was
- found 2.185gm/cc.
- The O.M.C. was found6.80%
- The average value of C.B.R. were found 44.42% which shows that the amended / modified RD material can be used for construction of G.S.B. layer30%

Wet Mix Macadam –

- RD waste of granular course was used for construction of new W.M.M. layer with addition of 10% 40mm course aggregate and 1% stone dust. The required physical tests were performed including sieve analysis and the results obtained from testes were found in specified limit.

- The conclusive results of physical test of amended / modified W.M.M. material obtained from testes are as below–

- The sieve analysis of RD waste material was not found in mid-range limits of MORT&H but after addition of 10% of 40mm course aggregate and 1% stone dust, the test results shows the desiredlimits.

- The water absorption percentage for amended /

modified W.M.M. material was found 0.28% for 40mm aggregate, 0.98% for 20mm aggregate, 0.74% for 10mm aggregate and 0.46% for stone dust which are under limit of Max. 2% specified by IS code 2386 (Part 3) : 1963

- For Atterberg Limits, the value of average liquid limit comes out 19.38% which was found below 25% specified by IS code 2720 (Part -5) :1985.
- The plastic property was not shown during test. So, the Plasticity Index is denoted as Non – Plastic (NP).
- The value of Flakiness Index was calculated 12.20% and the value Elongation Index was calculated 9.50% for amended / modified W.M.M. material. Hence, the Combined F.I. & E.I. was found 21.70%. This is less than35%.
- The A.I.V. of amended / modified W.M.M. material was found 23.41% which is less that 30% specified by IS code 2386 (Part -4) :1963
- The Max. Dry Density was found 2.210gm/cc.
- The O.M.C. was found6.30%

Scope for Further Study

- This study may expand in the following directions –

- Recycled aggregates can also be used to study the properties of other mixtures, such as asphalt andgravel.
- The effects of recycled aggregates treated by methods such as the "Heating and Friction Method" (HRM) may also be included in futurestudies.
- Performing an economic analysis may help quantify the financial benefits of using recycled aggregates instead of freshaggregates.
- The field performance of the test section may also be part of futureresearch.

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